Technical and Bibliographic Notes/Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

- [x] Coloured covers/ Couverture de couleur
- [x] Covers damaged/ Couverture endommagée
- [ ] Covers restored and/or laminated/ Couverture restaurée et/ou pelliculée
- [ ] Cover title missing/ Le titre de couverture manque
- [ ] Coloured maps/ Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black)/ Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations/ Planches et/ou illustrations en couleur
- [ ] Bound with other material/ Relié avec d'autres documents
- [ ] Tight binding may cause shadows or distortion along interior margin/ La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure
- [ ] Blank leaves added during restoration may appear within the text. Whenever possible, these have been omitted from filming/ Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

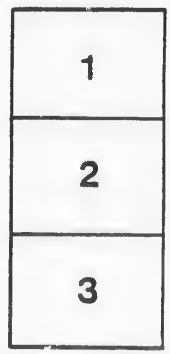
- [ ] Coloured pages/ Pages de couleur
- [ ] Pages damaged/ Pages endommagées
- [ ] Pages restored and/or laminated/ Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed/ Pages décolorées, tachetées ou piquées
- [ ] Pages detached/ Pages détachées
- [x] Showthrough/ Transparence
- [ ] Quality of print varies/ Qualité inégale de l'impression
- [ ] Includes supplementary material/ Comprend du matériel supplémentaire
- [ ] Only edition available/ Seule édition disponible
- [ ] Pages wholly or partially obscured by errata slips, tissues, etc., have been refilmed to ensure the best possible image/ Les pages totalement ou partiellement obscurcies par un feuillet d'errata, une pelure, etc., ont été filmées à nouveau de façon à obtenir la meilleure image possible.

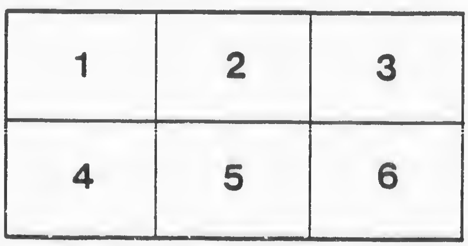
- [x] Additional comments:/ Commentaires supplémentaires: Pagination is as follows : [375] - 407 p.

This item is filmed at the reduction ratio checked below/
Ce document est filmé au taux de réduction indiqué ci-dessous.

10X	12X	14X	16X	18X	20X	22X	24X	26X	28X	30X	32X
							✓				


1
2
3


1
2
3


1
2
3
4
5
6

Mr. E. Haycock.

Proceedings of the Boston Society of Natural History.
Vol. 28, No. 15,
p. 375–407.

STUDIES IN THE GOLD-BEARING SLATES OF NOVA SCOTIA.

By J. Edmund Woodman.

WITH THREE PLATES.

BOSTON:
PRINTED FOR THE SOCIETY.
March, 1899.

No. 15. — *Studies in the Gold-bearing Slates of Nova Scotia.*

By J. Edmund Woodman.

With three plates.

CONTENTS.

General Statement.

Along the Atlantic side of Nova Scotia a series of gold-bearing rocks extends from Cape Canso irregularly westward to Yarmouth, in a belt which averages from ten to forty miles in width. It covers an area estimated at somewhat over 6,000 square miles; but fully half must be deducted for the many intrusions of granitic rocks. The sediments consist of slate, sandstone, quartzite, chloritic slate, and schist, always pyritiferous, and here and there a conglomerate. They have been profoundly metamorphosed, both by dynamic and igneous agencies. No fossils are known from them, and their exact age is in doubt. From the best fragments of evidence, however, they may be regarded as probably Algonkian. Between and occasionally cutting the strata are veins of quartz and calcite containing gold, both free and in the various sulphides, which are abundant. The sediments themselves are impregnated with sulphides, gold being found at considerable distances from veins. The whole mass, sediments and veins alike, has been thrown into east-west folds, and cross-folded and faulted north and south; and the crests of these folds have been denuded, fixing the location of the roughly elliptical mining areas.

During the season of 1897 I visited a number of the most promising portions of the series, with the intention of deciphering its history, as far as opportunity allowed. A review of certain points was possible during the following season. Much work has been done by local geologists in exploiting single areas; but, as far as the literature shows, no attempt has been made before to connect the bits of evidence which go to make up the story of the rocks. The region studied includes many of the exposures over an area roughly estimated at thirty miles square in the counties of Halifax and Colchester, and stratigraphically near the center of the series, where the auriferous slates and veins are most prominent. Special attention was paid to Moose River Mines, Gay's River Mines, Waverly, and Cow Bay.

I am greatly indebted in the prosecution of the research to Prof. N. S. Shaler, and to the officers of the several mining companies in whose shafts and tunnels I worked.

Structure and Characteristics of Portions of Halifax and Colchester Counties.

Sediments. — Two main divisions of the series were early recognized by Campbell ('63). Of these only the lower, called by him the quartzite group, contains workable bedded veins. The latter are exposed intermittently in belts, especially east of Mount Uniake.

The slates vary in texture, but their chief differences are due to secondary causes. The color is usually bluish; frequently, however, altered to green by chlorite, to brown by the oxidation of pyrite, or to a gray by the loss of iron upon highly weathered surfaces. Alternations of color in some places are frequent, while in others considerable masses may be uniform. This depends upon how thinly the rocks are bedded. Often, in the coarser sediments, leaves of schistose slate, only a fraction of an inch thick, will be found persistent for many feet. Again, it is a common condition for isolated sheets and lenses of slate to occur in the midst of a massive bed of sandstone.

The arenaceous sediments include what the miners call "whin." This term, originally used by Hutton in the sense of trap, and still employed in Cornwall with the same meaning, has been applied here to any kind of rock, other than slate, which cannot be mined.

Thus, one hears of the three-fold division of the series into ore, slate, and whin — the erroneous idea prevailing that neither slate nor whin is available as ore. As a whole, these coarser sediments are thickly bedded, and comparatively uniform in color and texture through a considerable thickness. They vary, however, in degree of consolidation from quite friable sandstone to dense quartzite; and, although prevailingly fine-grained, they grade into pelites on the one side and, through grits, into conglomerates on the other. Their color is generally dark green in unaltered specimens; upon weathering first becoming brown through oxidation of sulphides, then bleaching to a yellowish white.

At Moose River Mines and at Waverly the sediments can be studied readily. In the former settlement artificial outcrops are few, but a number of vertical faces in quarries can be used. At Waverly there are few pits, and the shafts follow veins; but natural exposures can be found, including a total of several hundred feet of strata.

Regional metamorphism affects the whole series. Both coarse and fine rocks have been hardened, although subsequently rendered fissile by cleavage. Muscovite, chlorite, and calcite have been developed in some cases along bedding-planes, in others along cleavage planes. A large proportion of the sandstone has been altered to a rock which always has been called quartzite by students of the series. It breaks with the lustrous fracture noticeable in that species; but microscopic examination shows that much of it is in a state which will not permit the use of the term. In these cases secondary deposition of silica is slight, while chlorite and muscovite are developed somewhat; calcite is abundant, giving free effervescence with acid. This is noteworthy, in view of the statement of several observers (Gilpin, '88, and others) that little lime is to be found in the series. In some cases it is not possible to tell whether the muscovite is fragmental or secondary, because of the small size of the particles. Occasionally the sediments become chloritic schists or mica-schists, and in many more instances the microscope reveals distinct schistosity in a minute way.

The presence and position of sulphides and sulph-arsenides in both classes of fragmental rocks and in veins deserve separate treatment. Gilpin ('82) mentions, as accessory to the gold, "sulphides and arsenides of iron, galena, blende, copper pyrites, oxide of iron, copper glance, molybdenite, native copper," etc. The principal sulphides are pyrite, arsenopyrite, chalcopyrite, and galena. The galena occurs only in veins, so far as my observations go. The others are present in both veins and sediments, and much the gold is locked up in them. Pyrite occurs in small cubes and minute granules, rarely in masses of several crystals; arsenopyrite is found in typical striated prisms, often half an inch long, and in massive form; chalcopyrite exists chiefly in irregular masses.

Pyrite is the most abundant sulphide, and in the sediments its attitude is characteristic. The strata have planes of division, unevenly distributed, which mark the more abrupt changes in texture and color, and along which the fissility is more marked. These may be called major planes of division. Between them are other minor planes at which the cohesion is greater, and which represent smaller changes in the conditions of sedimentation. In the slates the pyrite lies along major planes of division, and in some cases along minor ones, and is scattered sparingly through the mass of the stratum. Rarely it is irregularly distributed in large quantities within the bed. This position is so constant that, where stratification in the slate cannot be deciphered by color-bands and is obscured by cleavage, layers of pyrite, if present, serve to give strike and dip. Usually the mineral is abundant along the base of a layer and decreases upward. In other instances it is plentiful in the center of a bed and concentrated again at the division-plane. In the coarser strata it is less regular in distribution, but in general follows the same rules as in the slates. In veins a considerable amount is to be found, but it has no regularity of position. Frequently it protrudes from the sediments into the quartz. On the borders pyrite is often collected in sheets, chiefly on the hanging-wall. It is less abundant or absent on the foot-wall. In the oxidized zone near the surface, all this is brought out clearly; below that it is not so easy to find.

Arsenopyrite occurs most abundantly in the whin, distributed irregularly, often with its crystals lying at an angle to the bedding-planes. It is also situated sparingly along these planes, and in a few cases has been seen to lie directly across them, part being in one stratum, and part in the other. In veins it is common in massive form, but crystals are comparatively rare.

The whole metamorphic series is cleaved strongly. The strike of the laminae averages not far from that of the rocks in many localities, and is persistent throughout the series, showing unity in the force which produced it. Slates show this cleavage to a high degree. In many places the rock is given the sheen peculiar to those stages of metamorphism of slates on the way to becoming mica-schists and chloritic schists. The presence of the oxidized zone has not affected the degree of fissility to any marked extent in the region as a whole. Cleavage has more varied effects upon whin, which is quite brittle. Deep below the surface of the earth, the rock to the eye presents little fissiliry; but in the oxidized zone it is cleaved strongly in most instances, falling to pieces with ease under the pick. No doubt this result is aided by the stretching of pyrite, the crystals of which lie at the major planes of division; and the rusting of the sulphides and separation of the strata give a serrated appearance to the cross-section of the beds thus affected. Upon close examination, this serration is seen to be due, in some places at least, to strain-slip cleavage. Two places show this well. The first is at Moose River Mines, on the eastern face of a large quarry. The second is at West Waverly, about three hundred feet south of the old crusher west of the railroad track. Here a number of parallel thin lenses of slate, none of them more than a few inches in length, have been so sheared by the cleavage as to present the appearance of a series of ragged fringes overlapping one another, and giving the impression of involved igneous contacts.

The fissility is not all vertical; nor are its planes parallel over considerable areas, but dip now to the north, now to the south, always at a high angle. The axial planes between the two sets of dips, while in the main parallel to those of the folds first formed in the sediments, are not coincident with the latter, but may lie anywhere between the axes of the anticlines. The series is traversed by many joints. For the most part the systems formed by them are only local, and often several systems are to be found in the same territory.

Veins. — The chief interest in this series attaches to the gold-bearing stratified veins, often called "leads." These are from a fraction of an inch to six feet in thickness and in most cases of unknown length and depth. Many have been traced for a large fraction of a mile by intermittent outcrops, and this is probably only a small portion of their total length. Apparently they are not of unlimited extent, but die out and are replaced by others on adjacent planes. This has been reported from many mines, but has not been observed by me. They lie strictly in the bedding of the sediments as a rule, leaving it only to cut across abruptly from one stratum-plane to another. This irregularity is never so extensive as in the case of many veins filling ordinary fissures; and often the structure of a region can be deciphered by the inclination of the shaft-heads. In position, they sometimes lie between strata of slate, still more often on the contact between slate and sandstone or quartzite, and very seldom between beds of sandy material. It is common for a number of veins to lie parallel, separated by a few inches of country-rock; and these can generally be proved to have connection with each other. Both Moose River and Waverly show this. In the latter village the "barrel lead" east of the lakes is composed in places of parallel sheets of quartz, separated intermittently by thin laminae of slate, the whole forming one large vein. In very many places stringers, locally called "angulars," run out from the main veins into the country-rock above and below; and it is claimed by miners that they are most abundant in the hanging-wall of a "roll," and indicate the proximity of a pocket of gold.

The composition of the vein filling is uniform. By far the larger part of the gangue is quartz, which in many places is the only mineral; but often calcite is plentiful, erratically distributed. There is no definite order of growth, and frequently the quartz and calcite are indiscriminately mingled; yet in some cases quartz lines the walls, and calcite fills the interior. The former is usually compact, but seldom of the density and whiteness seen in many of the north-south barren fissure-veins. In places it has a cellular structure, showing successions of growth in the crystals; rarely drusy cavities are seen in the center of the veins, with free crystal terminations projecting into them. Frequently the quartz has been given a somewhat mealy appearance by the crushing which it has endured. Indeed, in its generally shattered and fragmentary state, most noticeable in thin veins, but observable often in thick ones, it bears witness to the action of powerful orogenic forces. The most complete shattering of the rocks, accompanied by small dislocations, usually is found where the folds plunge east and west; and for the most part the bedded veins have not taken advantage of the conditions. Much secondary growth has taken place, later additions of quartz, in some instances, increasing the thickness of the veins several fold. This is especially true in "rolls," to be described later, where the largest amount of accretion is to be observed. In places the successive layers or generations of growth can be seen distinctly, separated from one another by films of impurities or by differences in the alignment of the layers of quartz.

In regard to the origin of the bedded veins, two views have been held, as noted in the historical portion of this paper. The possibility that all the gangue was deposited as a mechanical or chemical precipitate in open water was early denied, and since 1870 has not been defended. Fissures which extend above and below the main veins, crossings from one stratum to another, and horses of country-rock enclosed in the quartz are irrefutable arguments against this view.

There is another hypothesis, however, which it would be well to consider, although it has not appeared in print before. The suggestion has been made that the veins began as films of sedimentary silica, and that they have grown by secondary deposition of material which has entered in solution, in the usual manner. There certainly has been growth, amounting in some instances to much more than the original thickness of the vein, and subsequent to its first formation. But where are we to look for films of silica deposited in the sea, and where not? Is such a primary layer present throughout the length of a single vein? If so, especially in the case of the longest ones, there must have been a remarkable uniformity of conditions on the sea-bottom; if not, considerable portions were formed by ordinary methods. Moreover, where the growth of the veins can be studied in the field, the evidence is of continual accretion inward, on both sides, as in other fissure-veins, and not from a central primary layer outward. In addition to this, the field conditions do not point to a sedimentary origin of *any* of the quartz. We know that silica can be dissolved, to an appreciable extent, in water of ordinary temperatures; but deposition of the substance in continuous sheets of some size would require a previous concentration of material from a larger region than it is easy to credit. Again, such a substance of necessity could be deposited in a pure state only in places where no mud and other coarser foreign particles were being dropped. Yet we find abrupt transitions from silica to slate, and from silica to coarse sand, the particles of which must have been deposited in water having a very appreciable motion.

It seems as though no more proof than has been given by previous writers is necessary to show that these are fissure-veins, and that the difference between them and others is merely in their attitude and the character and origin of the fissures.

If the quartz and calcite are not directly sedimentary in their nature, they must have one or more of three origins. They came from below, or from the surrounding rocks of about the same horizon, or from above. If they descended, the solutions must have been cold, and the same probably may be said if lateral secretion accounts for their presence. There were no cross-fissures, else the water would have deposited its burden in them. If any gold existed in the sediments, its collection might have been effected; but the concentration of gold appears to have taken place for the most part at a later date than that of the formation of the first crevices. Solutions would penetrate more readily the coarser and looser textured sandstones, and the finer grain of the pelites below would cause deposition of minerals along the contact. But we find veins at the under as well as the upper contacts of slate strata. If the clay intercepted descending solutions, the veins ought to be most frequent in the upper portion of the series, where there is abundant opportunity for such interruption. But they are by far the most common near the middle, where the proportion of slate to sandstone is greatest.

Against lateral secretion the same arguments hold, in part. The coarser beds do not look as though much silica had been carried through them in solution, for they have comparatively little secondary growth on the quartz grains. The silica necessary for the formation of the veins would have necessitated an extensive leaching of the surrounding rocks, and would have left its mark in the condition of those rocks; and the arenaceous sediments, which were formed principally from sand, would probably have received most of the veins.

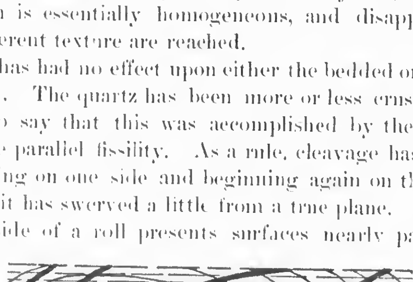
It is more natural, and in better accord with the facts, to suppose that, although the veins lie parallel to stratification planes, they came from below in the same way that many others have done, and were formed from hot waters which bore various substances in solution. Their distribution appears to have no reference to a possible local supply, but does agree with planes of weakness along which they could force their way under pressure. There is much calcite in the cement of the arenaceous sediments; and it might be supposed that at least this portion of the gangue came from them. But usually it is either closely mixed with the quartz or fills the interior of the vein, and thus appears to have a common origin with the silica, and to have entered the fissures at the same period.

There are very many veins filling crevices not coincident with stratification. These include, as one class, stringers connecting various bedded veins, and the "angulars" running off from them; but they belong to the age of the main leads, and need not be considered here. In addition there are "cross-leads," as they are called locally, younger than the others and independent of them, and filling irregular crevices or regular joints or fault-planes. In Nova Scotia they belong, in part, to a series running in planes of dislocation formed at the second period of folding and faulting, but erratically distributed, and not occupying all the faulted area. For the others it is impossible to find any system. Most of these and a large number of the former are barren; but at Cow Bay a definite series occurs, carrying a fair amount of ore.

The veins at that locality lie in nearly vertical fissures striking in general N. 25° W., and intersecting rocks which have the usual strike and an average dip of 40° S. The gangue is chiefly quartz, with some calcite. Pyrite and arsenopyrite are abundant, the latter massive. Galena and sphalerite are more common than in the bedded veins, and often are associated closely with gold, which is found free as well as in sulphides. The structure of the gangue is on the whole much more open and cellular than in stratified leads, and drusy cavities in the center of the mass are frequent, sometimes filled with galena and sphalerite. The quartz lies in part in distinct crystals perpendicular to the walls, in layers separated by films of impurities. However, in the larger veins the gangue is quite dense. The sulphides occur chiefly in the middle, and evidently were among the last minerals to form; but their order and position are not constant. In a few cases, chalcopyrite was the last mineral to enter, and includes other sulphides. Arsenopyrite is scattered through the gangue, and occasionally projects from the whin contact into the quartz. It is abundant also in the whin. Pyrite is perhaps the commonest sulphide, and often is found as a coating on horses. The galena is stated to carry silver.

The veins are very persistent in strike and dip; but they send out innumerable small branches into the country-rock, and often two master veins are connected through irregular cross-fissures which do not correspond to any definite structural feature of the sediments. The walls are far less definite than in the bedded veins. Horses are abundant, and in some cases the wall-rocks are brecciated for several inches and impregnated with minerals. The series lies, as far as my observation shows, within what may be regarded as essentially a single bed of whin. The latter is composed in reality of many heavily bedded strata interspersed with a few thin layers of slate carrying some veins of the bedded kind; but the proportion of slate to whin is exceedingly small. On the south of this belt, which is one or two miles broad, 2,000 feet of slate overlie the gold-bearing rocks. On the north those who live in the district report another broad band of slate, with a small amount of whin. The cross-leads die out on the margin of the slate on the south, and have been looked for in vain on the north. If the fissures extended beyond the belt of whin, veins would be found in them. It seems, then, that here may be a case on a large scale of what the studies of Mr. J. B. Woodworth have shown to be common in a small way — a system of joints, confined to a series which is essentially homogeneous, and disappearing when rocks of different texture are reached.

Cleavage has had no effect upon either the bedded or fissure-veins of the series. The quartz has been more or less crushed, but it is impossible to say that this was accomplished by the force which produced the parallel fissility. As a rule, cleavage has ignored the veins, stopping on one side and beginning again on the other, but occasionally it has swerved a little from a true plane. This happens where the side of a roll presents surfaces nearly parallel to the



Diagrammatic section of quartz vein in slate, Moose River Mines. Vein, white; stratification, light full lines; cleavage, light dashed lines; joints, heavy full lines.

cleavage, but departing from that relation gradually towards the top and bottom. The metals within the vein, and even on contacts between gangue and country-rock, have not shared in the general distortion, and thus appear to have been protected by their relations to the resistant quartz. The cleavage planes of the calcite in the veins are often curved; but it is not possible at present to designate which of the various orogenic forces concerned in the history of the series produced the result.

Structure. — The whole series of rocks is folded in a direction averaging N. 65° E. in Halifax county, becoming more northerly in the western part of the Province. It is noticeable that the general trend of the peninsula also changes correspondingly. The force producing these plications probably came from the south, although the evidence on this point is not clear. A second folding took place subsequently in a direction nearly at right angles to the former, culminating in an extensive series of faults, which strike roughly north-south. These newer flexures are said to be less frequent in the eastern portion of the field, and to become gradually more abundant westward. They have been equally instrumental with the earlier ones in locating the present mining settlements, by doming veins up so that denudation has given intermittent exposures.

The faults are both normal and reverse. As they were formed in the main by pressure, the latter are most abundant, and tension or gravity faults afforded local relief. In places their magnitude is considerable, the throw being several hundred feet. Most of them belong to the end of the second period of folding, and those formed as a result of the first plications are small.

The structures produced by these orogenic processes can be seen in most of the mining districts. Oldham, Renfrew, and Moose River Mines are cases in point. The first two have been mapped in a general way (Hind, '72). Of the last, a detailed map on a scale of 1 : 3,000 has been published by Mr. Faribault of the Geological survey of Canada.

In many places the bedding is smooth but in many others it is disturbed by corrugations, which vary from minute crenulations up to "rolls" several feet from crest to crest and two or more in depth. The large cases are known locally as "barrel quartz," and from smallest to largest are all the same in character and in origin. They start in veins, and are participated in by them and the adjacent slates, very rarely and only to a slight extent by other members of the series. They are found sparingly on the sides of the east-west anticlines, but are common where the axes of these are made to plunge downward by the doming effect of the north-south folding. In a few instances they may be horizontal; but usually they have a distinct pitch dependent upon the degree of inclination of the axes of the folds, the thickness of the leads, and the character of the country-rock. In this they are not exactly coincident with the bedding, for on a plunging axis they converge at smaller angles than those of the strike lines.

A noticeable feature is the local nature of the distortions. Near the vein the stratification of the slate follows closely the twisting of the quartz. As one recedes from it, however, the bedding-planes become less strongly crenulated, until from an inch to several feet away the waves die out. The coarser the sediment, the less it has yielded visibly to the forces; and in contact veins the quartzite wall is even, and the slate wall rolled more than is usual in veins which lie wholly within the slate, at some distance from any whin. The appearance suggests that there may be a compensation, the rigidity of the whin forcing greater buckling in the more plastic slates. In still other cases, where the vein is in slate, but within a few inches of a quartzite bed, the slate on the side toward the whin is crenulated and crushed till the particles have little power of coherence; and on the other side the rolling is regular and the slate bent without fracture. In general, however, the corrugation has weakened the sediments near it.

A structure similar to rolling is observable in sections of the Cretaceous clays and sands of the Atlantic coastal plain. In these water, often bearing iron, has buckled up the clay laminae in a manner precisely similar, leaving adjacent sands untouched. The phenomenon has no necessary relation to the concentration of gold, although barrel quartz is considered by many Nova Scotian miners as sure to be rich; but in some veins it appears that gold was either brought up by the new solutions, or concentrated from the sediments at about the time of corrugation, and now lies on the borders of these rolls in pockets.

In Moose River rolling can be studied in detail, although the lack of coincidence between the attitude of the rolls and that of the axes of the main folds is not very marked. The best places for observation are quarries near the road, and winding tunnels following the Great North or "Serpent" lead, which bears quartz over a foot thick flexed in large waves. The parallelism of quartz layers also is marked here. In the quarries much smaller examples show many points not brought out so clearly in the large cases.

At East Waverly occurs what must remain as the type case of rolled or barrel quartz. It has been described by some of the earlier writers, and in one or two cases figured in a diagrammatic way. The resemblance noted by Silliman and others to a corduroy road or a succession of barrels ceases when both sides of the vein are seen. Instead of a series of cylinders laid side by side, the rolls are merely what would be made by corrugating any flexible sheet, and their two walls are parallel for the most part. The lead lies almost on the contact between slate and whin, and the tunnels show both walls in many places. The adjacent slate is plicated as closely as the vein, while the hanging-wall of whin is perfectly even. The rolls are regular, and show a divergence with the bedding which increases as one goes towards the axis of the older fold at the end of the main tunnel. At West Waverly none of the leads have distinct rolls so far as observed.

In this district of Waverly, which embraces an area roughly two miles east and west, by one north and south, all the complications attendant upon the two series of orogenic movements are highly developed, and well revealed by erosion. For this reason I have chosen it for description as a type of the kind of structures originating in the Province under such circumstances. So far as I am aware, the form which it presents has been seldom noted in text-books, when treating of dynamical geology. It is thoroughly characteristic of the series, although presenting some individual peculiarities; and its main features are more accentuated than in most of the other cases which the series exhibits. On the eastern border, as at Isaac's Harbor, the main anticlines are so long that their plunging ends may not be met within the range of a single settlement.

The structure of East Waverly is that of an east-west anticline, which begins to plunge eastward at a very low angle beyond Willis Lake. Near lakes William and Thomas, at a point about 750 feet east of the shore road, it commences a steep plunge to the west, the vein dropping 185 feet in 425, and continuing downward at an angle of at least 50° when last seen, at lake-level. This vein, famous as the type of rolled or "barrel" quartz, has been well opened for several years. On the summit of the hill 1,200 feet of the crest of the fold have been exposed by open quarries, but nearly half of this distance is now obscured In addition, a tunnel runs 670 feet east along the axis from the lake-front, intersecting all the rock overlying the vein. From its end an up-raise is excavated along the vein, till the axis reaches nearly a normal horizontal position; and from the same point branch tunnels run north and south, following the strike of the vein in its change eastward, giving completely the structure of the pitching fold.

One of the points most noticeable in the openings, particularly in the quarries, is the flatness of the crown. This crown was the only portion exposed when the region was visited by Silliman and later studied by Hind, and gives a belt fifty feet wide in places, with almost no dip. This can be explained, however, by the fact — which a study of the whole field reveals — that it lies at the top of a folded series, and that it is immediately under a massive cap of whin. In contrast to this is the evenness of dip of the sides of the anticline. The vein in its descent soon reaches an angle which is almost constant throughout the vertical range observed, a total of 230 feet directly and of nearly 1,200 by means of the fault-blocks and shafts to the west. This must mean either that some of the folds to which we give full swelling sides in section should be drawn with straighter shanks and narrow but flat crests, or that the fold in question is larger and deeper than anyone has hitherto thought. If it be true that the deformation is more extensive than has been thought, it has a direct bearing upon the possibility of deep mining in the district — a plan which has been urged often by Canadian geologists, and as often rejected by conservative investors.

The tunnel shows that a thick cap of whin overlies the vein, with but few thin bands of slate and one or two small veins. The surface outcrops on the hills, north and south of the axis, show nothing but whin for at least 500 yards.

West of Fishing Lake is another area of whin, which, as far as my present study can determine, is a continuation of the cap overlying the barrel quartz lead of East Waverly. It runs for an unknown distance westward, at least to the line of the Intercolonial railroad. Its attitude can be discovered only by occasional thin bands of slate; and by these it appears to form the end of a fold pitching west, like the other portions of the field. As it lacks economic importance, detailed study of it has not been made. No bedded veins have been observed in it, but it contains several barren cross-leads striking roughly north-south and dipping east. The location of the fault on its eastern border is marked by an escarpment seventy-five feet high, which serves to bring out forcibly the difference in resistance of the whin and slate.

East of the whin cap are the fault-blocks that contain most of the profitable veins. The first of these has an up-throw of 967 feet, the flat portion of the barrel quartz lead at East Waverly being taken as a datum-plane. At the center of the anticline, immediately west of the railroad, appears a mass of whin of greater visible thickness than any other except the cap; and it seems to mark the base of this local gold series. The ledge presents a great contrast to that which exposes the summit of the series. Instead of lying in a broad flat crown, the beds dip steeply from the very axis, showing a greatly pinched condition of this portion of the fold. Outwardly north and south from this axial outcrop are many veins, some worked, others idle, and all running with the bedding. They must be far more numerous than the outcrops show; but here, as in Moose River and most other mining settlements in Nova Scotia, little or no attempt has been made to uncover the bed-rock in a trench across the strike and bring to light all the leads that come to the surface. Only three veins are shown upon the map, because of the small scale employed; but enough are set down to give the structure of the area. The edge of the slate series on the north has been determined in several places; but its extension westward in the curve shown on the map is partly inferred from the plunge of the fold and the relations of various beds. Drift hinders detailed work in most places where artificial exposures do not aid the observer. This is especially true on the south side of the fold, where few veins are mined; and as a result, the southern limit as given on the map is conjectural, and liable to a possible error of 400 feet. Indeed, it is probable that on account of greater denudation the margin is slightly farther to the south than is shown.

The pitch of the axis is not uniform, but is steeper at first, more gentle in the center of the block, and continues at a very gentle grade towards the western margin. This is shown by the convergence and dip of the leads where observable. The south dips are less steep than the north ones; hence the axial plane of the fold does not lie vertical, but dips somewhat southward. The denudation of a plunging anticline of this character would cause a slight northward migration of the surface outcrop of the axis where the plunge occurs. This is hardly appreciable, however, in a fold so little unsymmetrical. The same may be said of the axis at East Waverly.

The next fault-block presents some structural problems that cannot be solved with the present data. No veins are now worked south of the axis; and the position of those mapped in Hind's report ('69) is, in view of the errors of location of other structural features, problematical. On the north of the axis the veins have been thrown north 190 feet. This leaves two possibilities. The motion may have been a vertical one, the axis upon denudation remaining in the same position, and the veins on the south being thrown as far southward as the others migrated northward; or the whole block in its movement may have been wedged northward 190 feet. At Moose River the horizontal component is marked, and very probably conditions are the same here. This conclusion is provisional, but is based upon what appears to be a common method of faulting in the series. If it be correct, then there has been horizontal motion along an almost vertical plane, due to pressure from the south; and in a section along the axis it would appear as though no additional dislocation had taken place.

The admission of the two small fault-blocks west of the lakes rests upon two pieces of evidence. One of these is the map accompanying Hind's report mentioned above, which gives two faults. The other is the statement of the owner of the land on which the full-line portion of the fault lies, and who has uncovered the land in years past for certain leads. At present there are no outcrops, hence the direction of the veins in these two blocks cannot be determined directly. I have copied Hind's map in this respect, because there is no other authority. The offset of the easternmost block is based upon the same data as the existence of the third fault.

Ores. — In the sediments gold is largely in sulphides, even near the surface. Slate holds it in paying quantities often at considerable distances from veins, but some localities appear to have little. This may be due in part, however, to the lack of accurate tests in those places. At Moose River pure slate yields in crushing over $2.00 of free-milling gold per ton, and is as rich away from veins as near them. Whin is popularly supposed to be barren, but recent assays have shown gold up to one or two dollars per ton. Sufficient tests have not been made to show relations between the presence of gold in the whin and the proximity of veins. In the latter gold is more erratic than in the country-rock, and often a whole region is characterized by the presence of "pockets" with lean places between. Below the drainage level of the region most of the metal is in sulphides; and this proportion increases downward for some distance, as less and less water penetrates the rock. The free gold here, in the veins, occurs in the same forms and positions as in those nearer the surface. Within the oxidized zone above, some gold is free in the country-rock, and a large proportion in the veins. In the latter it occurs along the walls, tonguing into the gangue, or disseminated in fine particles through the latter. Where the metal lines the sides of rolls, it is usually bounded toward the country-rock by a rusted zone. From here it runs inward in stringers, often along distinct fractures. So far as I am aware, no analyses or assays have been made systematically, to discover how much is still imprisoned within the influence of water action. As a rule the free gold appears without distinct crystallization; but one crystal, having a dodecahedral form, has come to my notice, and a few others have been reported in years past. The one noted above came from Cow Bay, where it probably has a deep-seated origin.

The method of occurrence of gold in the veins of this series, its distribution in the country-rock, and its relations to sulphides point strongly to the conclusion that at least a large part was deposited in the sediments and has been long in process of concentration in the veins by water which comes downward from the surface. It is possible that not all the gold in a region of so complicated a history has the same source; but while some may have been brought up with the quartz, the facts so far observed do not show that more than a small share of it had that origin.

An exception to the sedimentary origin of the gold must be made in the productive fissure-veins observed thus far. Of these Cow Bay affords the best example. Here the metal occurs chiefly near the walls, but is not confined to that position. There is a local belief, well founded for certain veins, that values are higher in "rough" or cellular quartz. Examination of many specimens shows that the most frequent attitude is in planes parallel to the vein-walls, in quartz the crystals of which are not visible, or between layers of crystals. Where the veins cut across intercalated slate bands there is no corresponding change in the "carry" of the ore. This is against lateral secretion as a method of concentration. So far as seen, no gold occurs in whin, and the superjacent slate is reported to be barren by those who have tested it. Experience elsewhere shows that, when gold has come from the country-rock, its source has been chiefly slate. In this region the latter occupies scarcely one per cent of the section traversed by the veins; hence to have been leached of sufficient gold to give over an ounce per ton of quartz, as is yielded in some shafts, the rock must have been extraordinarily rich. There is no evidence whatever that this has been the case. On the other hand, the structure of the veins and the character and positions of the accompanying minerals point strongly to a deep-seated origin for the metal.

Eruptives. — The only eruptives that have come under my notice belong to the granitic series. Their general distribution can be seen on any of the later geological maps of the Province. The edge of one boss lies a short distance east of Waverly, but it has not been possible to give it a careful examination. What has been seen confirms the general conclusions of the later writers. The rock alters already metamorphosed strata; yet Gilpin in '82, and again in '85, agreed with Dawson in claiming the rough contemporaneity of the intrusion of the granites and the formation of the veins. In '88, however, Gilpin implied the greater age of the latter, in stating that by the intrusions they are not "changed from their normal character beyond any slight variation due to metamorphism of the small percentages of lime, etc., commonly occurring in them."

In Halifax another large mass of granite has its eastern boundary. The rock is a coarse hornblendic granitite, whose contact has not yet been studied closely. Near it the slate loses its fissile character and largely its jointing, and becomes harder and more compact. Between the granite and this portion of the slate, where I have seen it, is a rock which in the field appears to be a rather coarse trap. Microscopical study of the problem has not been possible. The granite near this trap is fine-grained, and becomes steadily coarser for half a mile away from the contact. As it grows coarser a porphyritic structure appears, the orthoclase crystals attaining a length of from one to one and a half inches. The rock as a whole is very feldspathic and weathers rapidly. This field west of Halifax is one which could be employed to great advantage in a study of the relations between the granites and the clastics.

Denudation. — The structure of the series as a whole is not well enough known to determine how much of the sediments originally deposited have been lost by erosion. Lower Carboniferous conglomerate near Gay's River contains metamorphosed slate and whin with fragments of the attendant quartz veins; and undoubtedly its gold is also derived from them. The older rocks at the contact with the conglomerate show a much denuded surface, with rounded projections, in appearance like small roches montonnées, and about four feet long. From the structure of the neighboring slates it seems probable that a great amount of the erosion had taken place before the lower Carboniferous was deposited, and that the proportion lost since that time is relatively small.

It cannot be determined yet whether the older rocks were above water during most of the time between their first folding and the era of the conglomerates, but this seems probable. Debris from the gold series has not been recognized in younger sediments, except in boulders of the age just mentioned. But if the auriferous rocks were submerged during the intervening period, or even during any considerable portion of it, we find it necessary to account for the disappearance of all the sediments that were laid down, not only over the area of gold rocks as now seen, but also over the territory occupied by such Carboniferous strata as lie directly upon the gold formation.

In a large measure the present topography was produced by pre-Pleistocene denudation. Drift has determined details in the course of many of the streams, but the main features were there before ice over-rode the land. In many places, as at Moose River and Cow Bay, the peneplain level is preserved. For miles the rock is within a foot or two of the surface, covered with a loamy soil or a growth of Sphagnum and other moisture-loving plants, whose presence is due to the sluggishness of the drainage. In others, as the region about Waverly, an uplift, which appears to have occurred since the peneplain was formed but before the Pleistocene epoch, has allowed the etching of broad waterways. The place just mentioned lies in a north-south valley which is the highway for a chain of lakes and connecting streams flowing northward across the peninsula to the Bay of Fundy. East of the junction between lakes William and Thomas, steep hills rise from the water's edge to a total height of 240 feet, the average being 190 feet. West of the lakes the faulted areas are low, scarcely more than fifty feet above the water at any point. Still farther west beyond Fishing Lake, the overlying whin, stratigraphically the highest area in the region, stands up as a hill sloping west, and presents an abrupt fault-scarp to the east. The surface of the higher hills may be taken as approximately the level of the peneplain. The etching has been due to the uplifting of blocks into heights of more rapid denudation, in consequence of which the durable whin overlying the auriferous slates has been removed and the softer rock below eroded to a lower level than the whin of the unfaulted areas to the east and west. Both fault-blocks in which the beds plunge westward have their steepness of surface in accordance with the dip of the beds, although not so high. At East Waverly the whin cap is eroded over the axis of the fold to within a few feet of the slate, and a view from the west shows a depression of the crest-line at that point, indicating a near approach to the unroofing of the anticline.

The distribution of mining regions and the shapes of the outcropping areas are due to the intersection of domes of various shapes by the peneplain surface.

History of the Series.

The question of the age of the series is as yet a matter of doubt, and it is probable that this uncertainty will continue until fossil evidence has been found. I can add nothing to what is already known, for all the "fossils" I have found turn out to be concretions which so far have not shown even an organic nucleus. The most rational view appears to me to be that of Becker ('95), who, after summing up the evidence given by various writers, concludes that the sediments are more probably Algonkian than Cambrian.

The following is an attempt to reconstruct the apparent history of the series from the data which are available at the present time.

Deposition, on a sea-floor somewhat irregularly rising and sinking. The lower division of the series is said to become coarser toward the top, indicating shoaling. Above this comes the finer grained upper member, which apparently shows a return to deeper water with more uniform conditions.

Consolidation, gradually, by weight of added sediments. Despite this tendency the pressure from above was sufficient to keep that part now forming the series in a plastic state. The original thickness, even after consolidation, must have been several times that of the beds which are exposed to-day. This is shown, not only by the amount which can be demonstrated to have been eroded even before lower Carboniferous times, but also by the almost entire absence of faults at the first period of folding.

Formation of bedded veins, by solfataric action from below. The main portion of the process took place rapidly, but some veining lingered until after part of the later jointing, or else at intervals new activities arose, in no case with the same power as the first. A small amount of gold may have been brought up in the solutions. The presence of the veins prevailingly in stratification planes is another point concerning the great pressure under which the series lay, and the cross stringers show that the rocks had already begun to suffer differential stresses sufficient to cause irregular fractures. Of the primary planes of weakness, those were most pronounced which lay at the contact of two beds of diverse physical characteristics, and the solutions chose these in many cases.

Metamorphism and concentration of much of the ore. The possibilities in regard to the origin of the pyrite and arsenopyrite may be grouped as follows. (1) The sulphides in both country-rock and veins may have a common or separate origin. (2) Those in the sediments may be the product of metamorphism of original ingredients, or may be due to solfataric action; and those in the veins may be concentrations from the sediments, or have resulted from the same process which filled the veins. Neither can be proved with the knowledge we possess at present. Both slate and whin are thickly impregnated with the sulphides, and as much away from the veins as near them; and often in positions where solfataric solutions must have penetrated very thoroughly and have gone far from their place of entrance. Besides, they are ordinary products of metamorphism, where the proper ingredients are present in the rocks. If their source were deep-seated, however, their relation to the veins remains to be determined. At present it is not possible to decide this with accuracy. It appears that much of the sulphides in the veins has been concentrated from the country-rock, like the gold.

Whatever the facts concerning the origin of the ingredients of the sulphides, their concentration is easier to follow. It occurred mainly before the first period of folding and, of course, after the entrance of the veins. The presence of the ores along bedding-planes, and their folding with the sediments, indicate this. This is true uniformly of the pyrite, and to a great extent of the arsenopyrite. In some places chalcopyrite appears in cleavage planes, in thin sheets with bright surfaces. In such cases it is still a question whether it was deposited there, or whether it has been drawn out by subsequent displacement. The gold was concentrated at the same time with the sulphides. The gathering took place under the influence of solutions percolating laterally and still more downward, as shown by the attitude of much of the ore. This movement has continued in a very small way ever since its beginning. The faults of the two periods of disturbance are rarely filled with ore, and where they are its origin is not clear. Regional metamorphism of the series, manifesting itself in yet other ways, belongs to the same period. The chlorite is chiefly in bedding-planes, as far as studied; but much remains to be learned. The same may be said of the secondary muscovite and calcite.

Granites may have come in between this and the next event, but probably not until after both periods of orogenic disturbance and before the cleavage. They are said to intrude between bedding planes in some places, and to have no perceptible influence upon the distribution of the veins, or of the gold in them or in the sediments; but few data are available. The granite at Halifax appears not to run into bedding-planes, nor do these planes seem to buckle up over the intrusive mass. One thing must be remembered, however, in any attempt to classify the intrusives of granite in a time-scale of the history of the series. We have no proof whatever that the areas of granite are all of the same age, and for the present the evidence presented by each batholitic mass must be examined separately.

First period of folding, giving east and west folds, with few faults, flexing veins and bedding-planes alike. The coarser grits were corrugated with as much ease as the finest pelites, as though the mass were quite plastic. This condition obtained from the lowest to the highest member of the series as we have it now, showing that vastly more of it existed then.

Second period of folding, extending forward for a considerable time and forming waves whose axes run roughly north and south. The action loosened the strata somewhat, giving opportunity for the following consequences.

Rolling of portions of the veins and adjacent beds, at points on the sides of the second series of folds where the axes of the first folds plunge. They were made by a revival of vein activity. Either some concentration of gold took place at the same time, as shown by certain pockets on the sides of rolls, or else all or part of this gold was brought up by the new solutions.

As regards origin, field evidence leads directly to the theory that rolling was caused in part by the north-south folding, in part by the slow entrance, subsequent to the formation of the veins, of more silica than could be accommodated readily in the space. The orogenic forces had created weakness. The new silica made its way along these planes, where pressure was relieved by parting of the strata. Not being satisfied with the space already provided, it buckled up the strata nearest it, whenever the surrounding sediments were not too unyielding, until the pressures were equalized and no more material could enter. Faulting, closing the second epoch of orogenic action. These dislocations ran in the direction of the newer folds, and cut off the rolls. In some instances simple joints were formed, without lateral movement. Where the second period of disturbance has not faulted the rocks, it appears in some regions to have jointed them north and south, and a few of the fissures are filled with veins. Other systems appeared probably at various times, and the history of each district must be studied separately. Very little mineralization took place after these last planes of separation were formed. In some places joints have curved in passing rolls, as cleavage has done.

Local revival of vein action, marked in such places as Cow Bay. The gold in the veins there probably entered from below with the gangue.

Cleavage, striking about N. 60 E., and cutting all the veins. The effect was produced by pressure apparently nearly parallel to that which gave the first folding. The conditions of the sediments were different, however, at this later epoch. Instead of the plasticity due to youth, lack of complete consolidation, and a considerable load of superincumbent rock, the force had to deal with rigidity, rendered greater by the quartz veins scattered through the mass, and probably with a much reduced load, which would of itself decrease plasticity.

After these occurred certain other details of the history, to which no definite order is assignable. An irregular local faulting is one of the latest in many places, and may be due to comparatively recent warping from some of the last oscillations of the peninsula.

This or some other orogenic movement of wide extent and slight effect has inclined the cleavage at most points. As it has not altered the strike of the planes of fissility, it acted parallel to the force which produced these planes. A small concentration of sulphides may have taken place also since the cleavage (Hamilton, '66); but the presence of sulphides in the planes may be due, on the other hand, to the stretching and shearing of crystals which lay in the bedding. These occurrences often accompany bright slickensides. Veins of various ages fill irregular fissures, and are generally barren. I have not found any penetrating into the lower Carboniferous rocks, and believe that they are all older than this period but younger than the cleavage and most of the jointing.

How many cycles of erosion the series has suffered cannot be determined. At Gay's River Mines all the features noted elsewhere can be seen in the rocks underlying the lower Carboniferous conglomerate, but stop at its base. The latter has suffered no disturbance sufficient to fold or fault it, although slickensides on the pebbles and cement tell of internal movement. It is highly probable, therefore, that all of the effects outlined above had been completed long before that time, for the boulders in the conglomerate, largely from the slate and whin and veins, exhibit the same phenomena as the underlying rocks. The structure of the older sediments, and the character of their contact with the conglomerate above, show that the former series was denuded before Carboniferous times, probably the larger part of the original mass having been lost. The history since the Carboniferous is in great measure problematical, but what we know of the structure indicates that the topographic changes have been far less than those which took place before.

Summary of Early Studies.

The metamorphic series early attracted the attention of observers, but the main activity shown in its study was manifested immediately after the discovery of gold about 1860. On the whole, the work done upon the rocks has been unsystematic, with the exception of that carried on by the Geological survey of Canada. The following notes are arranged chronologically, to give the advance in knowledge of the whole series rather than of particular problems connected with it.

Jackson and Alger ('32) noted the slates, finding granite protruding through them. The latter are the older, and the sediments were laid horizontally upon them.

Gesner ('36) first mapped the series definitely, giving also a brief description. In '43 he made another map and description, publishing the former in '45. The lowest of the metamorphic sediments he called Cambrian, and described as graywacke, clay slate, becoming micaceous and chloritic in places, and quartz rock. General relations with the granites on the north and south were shown.

Dawson ('50) called the rocks "compact and flaggy quartzite (often weathering white), mica slate, and clay slate." He recognized the granites as intrusive, and considered the sediments lower Silurian or older. In 1855 he referred to them as lower than the Devonian, and perhaps equivalent to the Potsdam, Utica, and Hudson River beds elsewhere. A general map shows the distribution of the formation, and calls it "perhaps altered lower Silurian." In '50 he suggested that it may correspond to the Paradoxides zone in Newfoundland, a position approved by Billings ('60).

The date of the original discovery of gold is unknown. The sands of the Avon were panned many years ago as a pastime. It is more than a century since Waverly was said to contain gold, but no active work was done until '58 (Gilpin, '86). A somewhat later date has been given by Marsh for the discovery, who stated in '61 that it was first seen in March of that year, in the bed of a small tributary of the Tangier River, and soon after in quartz veins. In the same paper he noted the irregularity of strike of the veins at Tangier, and the probable obliteration of all fossils in the sediments by regional metamorphism. Where the slate carries gold, the value of the veins is not diminished, and on the whole the quartz is less pockety. The metal probably comes from the slate.

Dawson ('61) considered the veins "strictly a continuation of those which run along the eastern Appalachian slope as far as Alabama."

Campbell ('62) thought the leads true veins, lying mainly in the bedding-planes, but occasionally crossing them. Marcou, in the same year, referred the rocks to the Taconic system. Honeyman ('62) described Allen's and Laidlaw's property at Waverly. In the former mine the veins are nearly vertical, and stratigraphically lower than at Laidlaw's, where they lie flat, "somewhat like a stratum."

Campbell ('63) gave a generalized section across the series, and divided the rocks into a lower or quartzite group and an upper or slate group. He regarded the cross-leads as younger than the bedded veins.

Hartt ('64) proved the pre-Carboniferous age of the concentration of gold, by its presence in lower Carboniferous conglomerate, in boulders of the metamorphic series. The leads in the lower rocks end abruptly upward against the conglomerate.

Dawson ('68) mapped the outlines of the series in a general way, and called attention to the clay slates near the Atlantic coast. Hunt ('68) called the bedded veins contemporary sedimentary deposits, as did also Hind a year later ('69). In the latter paper the first announcement of fossils was made, the forms given being *Palaeotrochus major* and *P. minor* (Emmons), with accompanying concretions. Many similar reports have been made since, but in no case is the status of the form well established. As yet, nothing has been found so clearly organic that it is of the least value for evidence. By means of these fossils Hind sought to establish the series as upper Potsdam and lower Calciferous, and equivalent to the gold-bearing rocks of North Carolina described by Dr. Emmons. He also mentioned eruptive bedded rocks at Waverly, calling them "diorites, diabase, dolerite, etc." In the next year ('70, '70[b], '70[d]) he gave the thickness of the whole series as 12,000 feet, with Huronian strata below. The granite which protrudes through it was stated to be sedimentary and older than the auriferous rocks, its apparent intrusion having been caused by up-faulting while in a plastic condition.

Selwyn ('72) considered that the opening and filling of the stratification planes, the slaty cleavage, and the rolling of the quartz were all produced by the same force. The veins are thus true veins, and younger than the country-rock. He mentioned the discovery by himself of Eophyton at the Oven's Bluff; and from this and other evidence concluded that the series "resembles the Cambrian and the Lingula-flag series of north Wales."

Dawson ('78) called the rocks Cambrian, but admitted the imperfection of the evidence.

Poole ('80) found horses of slate in veins at Tangier, and stringers running into the country-rock; thus proving beyond doubt that the deposits are true veins. At the same place a bedded lead is capped and penetrated by gra[nite,] showing the greater age of the former.

Mica and feldspar occur with the quartz as gangue minerals. How ('68) had already reported albite from Waverly.

Murray ('81) compared the series with the gold-bearing strata of Newfoundland underlying the Aspidilla or St. Johns slates, deposited, apparently, at the close of Algonkian times.

Gilpin ('82) distinguished only one period of folding. The strata were opened and the rolls formed at the same time and by the same force, the veins entering subsequently at an unknown date. The bedded veins were filled to a great extent before lower Carboniferous times, the cross-leads perhaps after that period. Later ('86) he assigned the series to the lower Cambrian, and called the veins and granite intrusions roughly contemporaneous.

Faribault ('87) regarded the Eophyton of Selwyn as inorganic. He divided the rocks of the series into an upper graphitic and a subjacent lower Cambrian division. The latter contains 15,000 feet of strata, 11,000 of which are in Campbell's lower group and 4,000 in his upper division.

Gilpin ('88) placed the summit of the auriferous beds 2,800 feet below the base of the upper slate group, and gave them a thickness of 5,000 feet. They contain little carbonate of lime, while the veins contain much. The latter are associated with predominant slates and fine-grained whin, and their filling appears to have come from the country-rock, especially the slate. The granite intrusions are probably later than the folding, although in places they tongue into the sediments along the bedding-planes.

Walcott ('91) thought that the Cambrian may be represented in the gold series, but much of it is older.

Van Hise ('92) regarded Eophyton as organic, but considered the series as probably Algonkian.

Becker ('95), after compiling the written evidence on the subject, considered the veins to have been formed by the same force that produced the cleavage.

Problems for Solution.

Perhaps of chief importance in the study of the rocks is to ascertain their age with some degree of certainty. This can be done only by discovering fossils more unequivocally organic and of more stratigraphic value than any now known along the borders of the series.

For these, it would seem that some of the least metamorphosed sandstones present the best opportunities.

The petrographic character of the sediments, the contact metamorphism near granite bosses, the character of these intrusions, all must receive careful treatment before the history of the series can be well understood. An examination of the metamorphism of the sediments will throw some light upon the origin of both veins and gold, and upon the history of the latter. The so-called pre-Cambrian volcanics in the eastern part of the Province also may have some connection with the auriferous series, and deserves the attention which is being paid to the old extrusions of the Atlantic coast farther south.

In connection with the occurrence of the gold, the reason for its prevalence in the argillaceous members of the formation, which is not so simple as that of the frequency of veins in the same rocks, may receive at the hands of another an answer different from the one given here. The age, progress, and extent of the denudation of the series has yet to be studied, and may throw light upon the distribution or concentration of the gold which has been removed during the process. Finally, the nature, origin, and direction of the two great orogenic forces which have influenced the series have not been studied with the care they deserve.

LITERATURE.

Anderson, W. J.

'64. Gold fields of Nova Scotia. Trans. lit. and hist. soc. Quebec. new ser., pt. 2. p. 35–50.

Bailey, L. W.

'95. Preliminary report on geological investigations in southwestern Nova Scotia. Ann. rept. geol. surv. Can., 1892–93, rept. Q, 21 pp., map.

Becker, G. F.

'95. Gold fields of the southern Appalachians. Sixteenth ann. rept. U. S. geol. surv., pt. 3, p. 251–331.

Billings, E.

'60. [Review of] Acadian geology and a supplementary chapter thereto. Can. nat., vol. 5, p. 450–455.

Campbell, J. S.

'62. Report on gold fields, eastern section. Halifax. 1862, 8 pp.

Campbell, J. S.

'63. Report on the gold fields of Nova Scotia. Halifax. 1863, 12 pp.

Dawson, J. W.

'46. A handbook of the geography and natural history of the Province of Nova Scotia. Picton, 1846.

Dawson, J. W.

'50. On the metamorphic and metalliferous rocks of eastern Nova Scotia. Quart. journ. geol. soc. London, vol. 6, p. 347–364, map.

Dawson, J. W.

'55. Acadian geology. 1855.

Dawson, J. W.

'57. On the parallelism of the rock formations of Nova Scotia with those of other parts of America. Proc. Amer. assoc. adv. sci., vol. 10, p. 18–25.

Dawson, J. W.

'60. Supplementary chapter to the Acadian geology. Edinburgh, 1860.

Dawson, J. W.

'61. On the recent discoveries of gold in Nova Scotia. Can. nat., vol. 6, p. 417–432.

Dawson, J. W.

'68. Acadian geology. The geological structure, organic remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island. Ed. 2. London, 1868.

Dawson, J. W.

'70. Supplement to Acadian geology, 1870.

Dawson, J. W.

'78. Acadian geology. Ed. 3, London, 1878.

Dawson, J. W.

'88. On the Eozoic and Paleozoic rocks of the Atlantic coast of Canada, in comparison with those of western Europe and of the interior of America. Quart journ. geol. soc. London, vol. 44, p. 797-817; vol. 45, p. 80 Proc. Can. rec. sci., vol. 3, p. 82, 83, 230, 271.

Faribault, E. R.

'87. Report on the lower Cambrian rocks of Guysborough and Halifax counties. Geol. nat. hist. surv. Can., rept. for 1886, pt. P, p. 129-163.

Fletcher, H.

'87. Report on geological surveys and explorations in the counties of Guysborough, Antigonish, Colchester, Pictou, and Halifax, Nova Scotia, from 1882 to 1886. Geol. nat. hist. surv. Can., rept. for 1886, pt. P, p. 1-128, 2 plates.

Gesner, A.

'36. Remarks on the geology and mineralogy of Nova Scotia. Halifax, 1836, 272 pp., map.

Gesner, A.

'43. A geological map of Nova Scotia, with an accompanying memoir. Proc. geol. soc London, vol. I. p. 186-190. [Map published 1845, with papers of Dawson and R. Brown.]

Gesner, A.

'45. Geological map of Nova Scotia. Quart. journ. geol. soc. London, vol. I, opp. p. 23. [Accompanying papers by Dawson and Richard Brown.]

Gesner, A.

'49. The industrial resources of Nova Scotia. Halifax. 1849.

Gilpin. E.

'82. The gold fields of Nova Scotia. Engin. and min. journ., vol. 34, p. 5 6; 17-18.

Gilpin, E.

'8?. The trap minerals of Nova Scotia. Trans. Nova Scotian inst. nat. sci., vol. 5, p. 283-296.

Gilpin, E.

'85. Results of past experience in gold-mining in Nova Scotia. Rept. Brit. assoc. adv. sci., vol. 53, p. 711-712.

Gilpin. E.

'86. Nova Scotia gold mines. Trans. Amer. inst. min. engin., vol. 14, p. 671-689, map.

Gilpin, E.

'88. Notes on the Nova Scotia gold fields. Trans. roy. soc. Can., vol, 6, sect. 4, p. 63-70.

Gilpin. E.

'90. The evidence of a Nova Scotia Carboniferous conglomerate. Trans. roy. soc. Can., vol. 8, sect. 4, p. 117-121. Abstract, Science, vol. 15, p. 373.

Gilpin, E.

'98. Ores of Nova Scotia. Halifax, 1898, 46 pp.

Gossip, W.

'64. The rocks in the vicinity of Halifax]. Proc. and trans. Nova Scotian inst. nat. sci., vol. 1, pt. 2, p. 44-59.

Gossip, W.
'65. On the barrel quartz near Waverly. Proc. and trans. Nova Scotian inst. nat. sci., vol. 1, pt. 3, p. 141–142.
Hamilton, P. S.
'66. Auriferous deposits of Nova Scotia. Proc. and trans. Nova Scotian inst. nat. sci., vol. 1, pt. 4, p. 43–51.
Hartt, C. F.
'64. Pre-Carboniferous gold. Can. nat., new ser., vol. 1, p. 459–461.
Heathington, A.
'68. Guide to the gold fields of Nova Scotia. 1868.
Hind, H. Y.
'69. Report on the Waverly gold district. Halifax, 1869, 62 pp., map.
Hind, H. Y.
'69a. Gold deposits of Nova Scotia. Can. nat., new ser., vol. 4, p. 229–240.
Hind, H. Y.
'70. Notes on the structure of the Nova Scotia gold districts. Proc. and trans. Nova Scotian inst. nat. sci., vol. 2, pt. 3, p. 102–109.
Hind, H. Y.
'70a. Preliminary report on a gneissoid series underlying the gold bearing rocks of Nova Scotia, and supposed to be the equivalent of the Laurentian system. Halifax, 1870, 15 pp.
Hind, H. Y.
'70b. On two gneissoid series in Nova Scotia and New Brunswick, supposed to be the equivalents of the Huronian [Cambrian] and Laurentian. Quart. journ. geol. soc. London, vol. 26, p. 468–479, map.
Hind, H. Y.
'70c. On the Laurentian and Huronian series in Nova Scotia and New Brunswick. Amer. journ. sci., ser. 2, vol. 49, p. 347–355.
Hind, H. Y.
'70d. Report on the Sherbrook gold district, together with a paper on the gneisses of Nova Scotia and an abstract of a paper on gold mining in Nova Scotia. Halifax, 1870, 79 pp., 4 maps.
Hind, H. Y.
'72. Report on the Mount Uniake, Oldham, and Renfrew gold mining districts. Halifax, 1872, 136 pp., plates.
Honeyman, D.
'62. On the geology of the gold fields of Nova Scotia. Quart. journ. geol. soc. London, vol. 18, p. 342–347.
Honeyman, D.
'70. Geology of the Gay's River gold field. Proc. and trans. Nova Scotian inst. nat. sci., vol. 2, p. 76–81.
How, H.
'68. Mineralogy of Nova Scotia. 1868.
How, H.
'69. The mineralogy of Nova Scotia, a report to the provincial government, vi. Halifax, 1869, 217 pp.
Howe, J.
'60. Report on the gold fields. Halifax, 1860.

Howe, J.
'60a. Tangier mines. Report to the provincial secretary. Halifax, 1860, 6 pp.
Howe, J.
'61. Nova Scotia gold fields. Letter to the provincial secretary. Halifax, 1861 7 pp.
Howe, J.
'61 . Nova Scotia gold fields Report to the provincial secretary. Halifax, 1861, 1 pp.
Howe, J.
'71. Report on gold fields. Halifax. 1871. 7 pp.
Hunt. T. S.
'68. Report on the gold regions of Nova Scotia. Geol. surv. Can., rept. for 1868. 38 pp.
Jackson. C. T., and Alger. F.
'32. Remarks on the mineralogy and geology of the peninsula of Nova Scotia. 116 pp., colored map.
Jackson. C. T., and Alger. F.
'33. Remarks on the mineralogy and geology of Nova Scotia. Mem. Amer. acad. arts and sciences. new ser., vol. 1, p. 217–330.
Logan. W. E.
'63. Geological survey of Canada. report of progress from its beginning to 1863. 938 pp., map.
Logan. W. E.
'65. Atlas of maps and sections.
Logan. W. E.
'69. Geological maps of Canada and adjacent regions.
Marcou. J., and Jackson. C. T.
'62. Note on gold slates of Nova Scotia. Proc. Bost. soc. nat. hist., vol. 9, p. 47.
Marsh, O. C.
'61. The gold of Nova Scotia. Amer. journ. sci., ser. 2, vol. 32, p. 395–400.
Matthew. W. D.
'95. The volcanic rocks of the maritime provinces of Canada. Bull. New Brunswick nat. hist. soc., no. 13, p. 76–83.
Moncton. G. F.
'94. The auriferous series of Nova Scotia. Proc. geologists' assoc., vol. 11, p. 151–161.
Murray. A.
'69. Geol. surv. Newfoundland, rept. for '68.
Murray. A.
'81. Geol. surv. Newfoundland, rept. for '80.
Perley, H. F.
'65 Gold in Nova Scotia. Can. nat., new ser., vol. 2, p. 198–219.
Poole. H.
'62. Report on gold fields, western section. Halifax, 1862, 25 pp.
Poole. H., How, H., and Campbell. J.
'62. Additional papers on the Nova Scotia gold fields, including Messrs. Poole and Campbell's reports. Halifax, 1862, 36 pp.

Poole, H. S.
'80. The gold-leads of Nova Scotia. Quart. journ. geol. soc. London, vol. 36, p. 307–313.

Prest, W. H.
'95. Deep mining in Nova Scotia. Proc. and trans. Nova Scotian inst. nat. sci., vol. 8, p. 420–434.

Selwyn, A. R. C.
'72. Notes and observations on the gold fields of Quebec and Nova Scotia. Geol. nat. hist. surv. Can., rept. for 1870–71, p. 252–282, map.

Silliman, B., Jr.
'64. On the so called "barrel quartz" of Nova Scotia. Amer. journ. sci., ser. 2, vol. 38, p. 104–106.

Silliman, B., Jr.
'64a. Report on the Lake Loon gold mining company. 1864.

Silliman, B., Jr.
'64b. Report on the New York and Nova Scotia gold mining company. 1864.

Van Hise, C. R.
'92. Correlation papers–Archean and Algonkian. Bull. 86, U. S. geol. surv., p. 239–247, 502–503.

Walcott, C. D.
'91. Correlation papers — Cambrian. Bull. 81, U. S. geol. surv., p. 56–59; 262; 380.

Anon.
'63. Gold commissioner's report for 1862. 1863.

Anon.
'70. Report of the chief commissioner of mines for the province of Nova Scotia for the year 1869. 1870.

Anon.
'74–'99. Report of the department of mines, Nova Scotia, in annual volumes, for the years 1873–'98. 1874–99.

Printed, March, 1899.

PLATE I.

Map of Waverly, scale 1: 14,400. A, upper whin; B, auriferous slate with leads; C, lower whin. Contacts are lines of dash and two dots; faults, dash and dot; veins, dash; axis of anticline, full heavy line.

Section of same, along axis of fold. Horizontal scale, 1: 14,400; vertical scale, 1: 24,000. Symbols and lines same as in map. Where the axis is offset by faulting, the section, for convenience, still follows it, except in the case of the two narrow blocks on the east, where it keeps its previous trend.

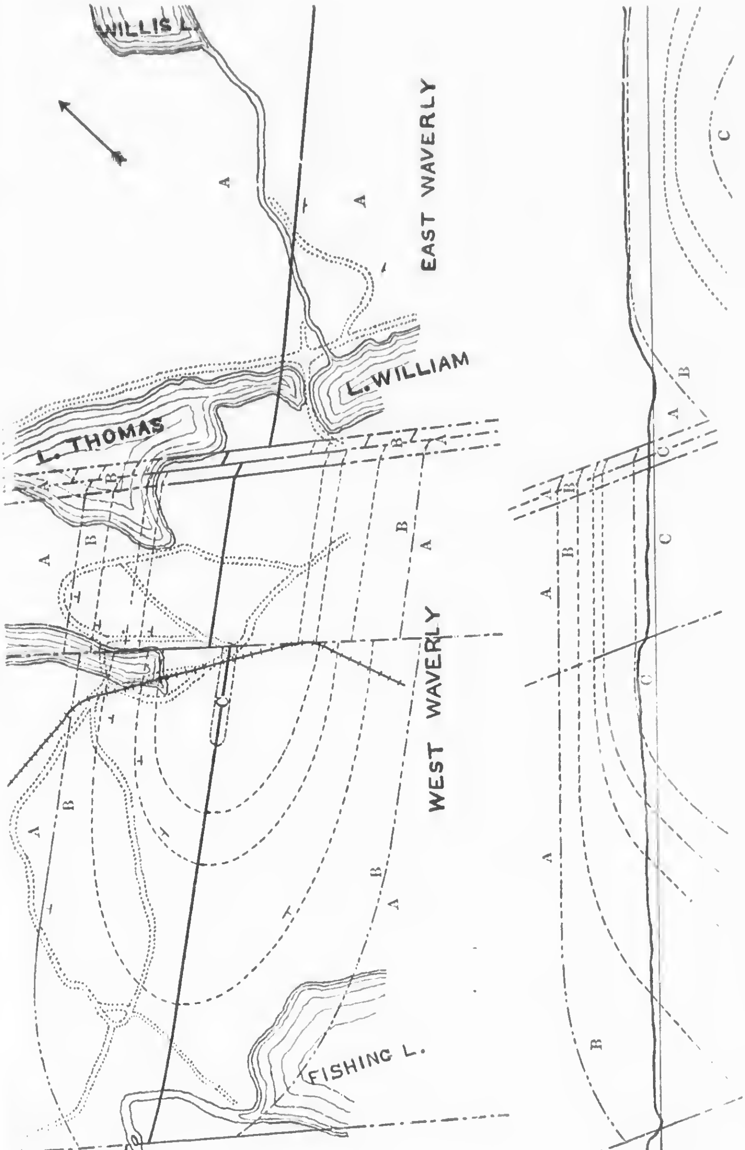

WILLIS L.
EAST WAVERLY
L. WILLIAM
L. THOMAS
WEST WAVERLY
FISHING L.

PLATE 2.

Section of the barrel quartz lead at East Waverly, showing true dip. Taken on northwest side of plunge.

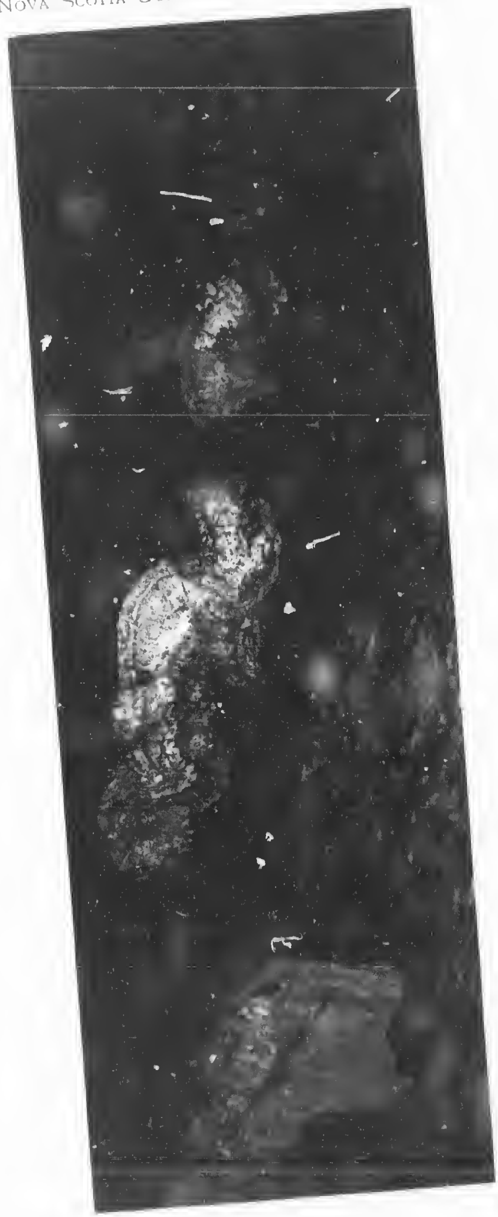
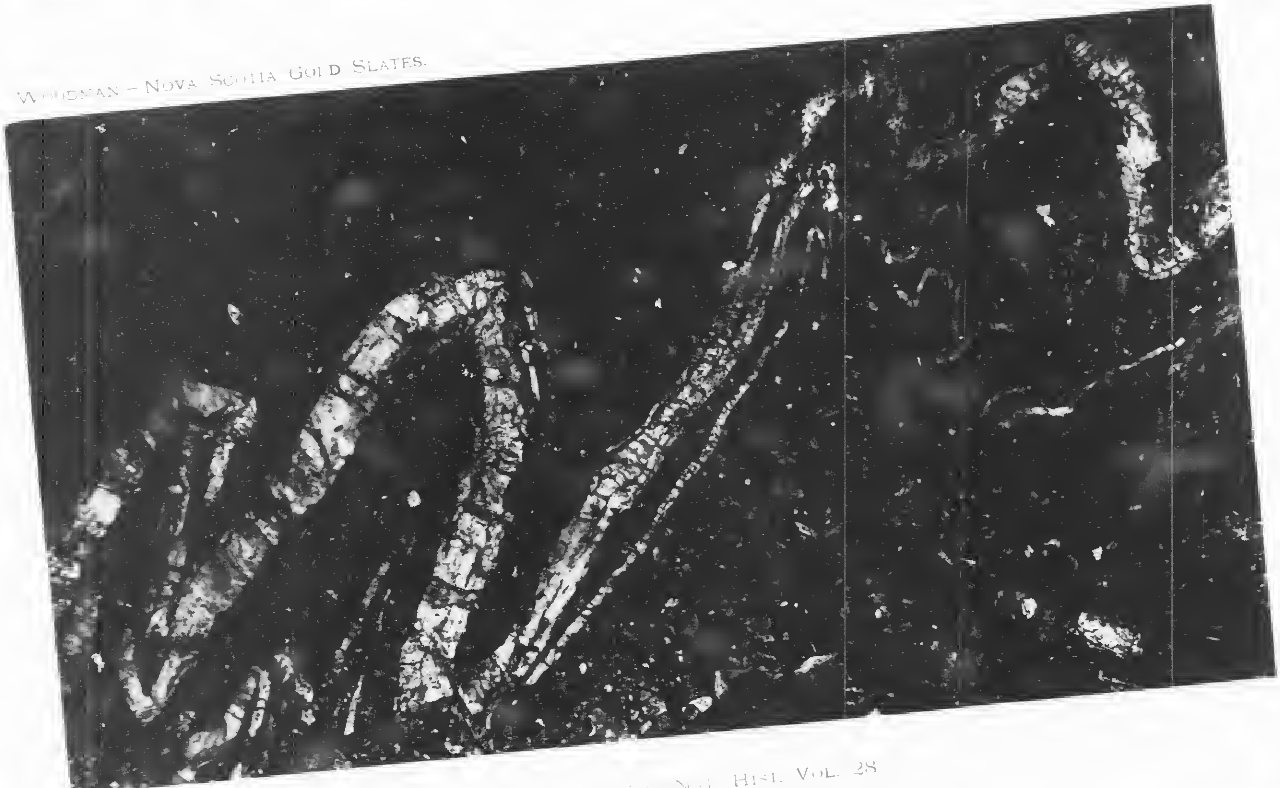


PLATE 3.

Section of Great North or "Serpent" lead, Moose River Mines, near the crest of the anticline.



THE HELIOTYPE PRINTING CO. BOSTON

Boston Society of Natural History.

RECENT PUBLICATIONS.

North American wood frogs. By Reginald Heber Howe, Jr. 6 pp. 10 cts.

Some Hydroids from Puget Sound. By Gary N. Calkins. 35 pp., 6 plates. 50 cts.

The Odonate genus Macrothemis and its allies. By Philip P. Calvert. 32 pp., 2 plates. 50 cts.

On the veins of the Wolffian bodies in the pig. By Charles Sedgwick Minot. 10 pp., 1 plate. 25 cts.

Notes on a Carboniferous boulder train in eastern Massachusetts. By Myron L. Fuller. 14 pp. 15 cts.

The genus Antennaria in New England. By Merritt L. Fernald. 13 pp. 15 cts.

The land mammals of peninsular Florida and the coast region of Georgia. By Outram Bangs. 79 pp. 75 cts.

A contribution to the petrography of the Boston Basin. By Theodore G. White. 40 pp., 5 plates. 65 cts.

Clymene producta sp. nov. By Margaret Lewis. 5 pp., 2 plates. 15 cts.

The Harvard geographical models. By W. M. Davis. 26 pp., 4 plates. 25 cts.

The role of water in growth. By C. B. Davenport. 12 pp. 15 cts.